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# Turtles in Malaysia: a review of conservation status and a call for research

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**Simple Summary:** Turtles were threatened all over the world. Malaysia has 24 species of turtles. The review focuses on some recent conservation status and requirements for sustainability. We proposed the integration of concepts between ecology and molecular biology to provide almost comprehensive turtle reviews in Malaysia.

**Abstract:** Approximately 356 species of turtle inhabit saltwater and freshwater habitats globally, except Antarctica. Twenty-four species of turtles have been reported in Malaysia, four of which are sea turtles. The state of Terengganu harboured the highest number of turtles, with 17 different reported species. This review discussed the checklists, molecular genetics work, conservation status, recent trends, and recommendations for future research on turtles in Malaysia. Based on the IUCN Red List, 29% of turtle species in Malaysia are critically endangered, while another 25% are categorised as endangered, Likewise, CITES also reported that 67% of Malaysia's turtles are threatened, while 25% are categorised as critically endangered. Factors contributing to their population declines and current endangered status were also discussed.

**Keywords:** taxonomic; sea turtles; checklist; ecology and genetic; IUCN Red List; CITES; endangerment

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## 1. Introduction

The term "turtle" is frequently used to refer to sea turtles, which only rarely leave the sea [1]. Sea turtles belong to the Cheloniidae and Dermochelyidae families, with the exception of the Leatherback turtle, which has a leathery carapace [2]. There are approximately 356 species of turtles living on land on every continent except Antarctica, as well as in salt water and fresh water [3]. These seven species of sea turtles are: Green turtle (*Chelonia mydas*), Hawksbill turtle (*Eretmochelys imbricata*), Leatherback turtle (*Dermochelys coriacea*), Loggerhead turtle (*Caretta caretta*), Flatback turtle (*Natator depressa*), Olive ridley turtle (*Lepidochelys olivacea*), and Kemp's ridley turtle (*Lepidochelys kempii*) [4]. Malaysia is home to

four marine turtle species: the Leatherback turtle, the Green turtle, the Olive ridley turtle, and the Hawksbill turtle [5]. With nearly 40% of its total body mass made up of bone, the turtle is possibly the most organised form of animal armour ever to appear [6]. As a result, this remarkable armour is most likely the reason turtles appeared on the scene over 200 million years ago and miraculously survived the extinction of the dinosaurs and other devastation [6].

Turtles, in the Testudines order, are any reptile with a hard shell around its body, including tortoises [7]. They have anatomical characteristics that set them apart from other turtles. A turtle, a tortoise, and a terrapin are all names for hard-shelled, egg-laying reptiles in the Chelonia order [8]. However, the specific expression used for a specific turtle can vary depending on its natural surroundings. For example, the term "turtle" usually refers to turtles that have spent their entire lives in or near water [9]. The term "tortoise" is more commonly used to refer to turtles that spend the majority of their time ashore, eating bushes and grass [10]. Tortoises, unlike their turtle family members, do not have webbed feet because they do not spend much time in the water [11]. Terrapins are turtles that invest energy in both freshwater and brackish water [12]. "Terrapin" is derived from an Algonquian Indian word that means "a small turtle" [13]. Peninsular Malaysia is home to 20 different kinds of tortoises. Two of them, *Pelodiscus sinensis* and *Trachemys scripta*, were brought there from other places [14]. In total, Malaysia has 24 different species of turtle [15].

The most established bodies in conservation biodiversity are the IUCN (International Union for Conservation of Nature) and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). The IUCN Red List is a rich compendium of information on threats, ecological requirements, habitats of species, and conservation actions that can be taken to reduce or prevent extinctions [16,17]. It is a target framework for evaluating the extinction risk of species depending on past, present, and extended threats [18]. The assessments are carried out following a standardised procedure that employs the rigorous IUCN Red List Categories and Criteria, ensuring the highest scientific documentation standards, information management, expert review, and justification [16,19]. Increased assessments will aid in the development of the IUCN Red List as a more comprehensive 'Barometer of Life' [20]. Threatened species include those listed as Critically Endangered, Endangered, or Vulnerable [21].

The CITES is an international agreement between governments [22]. It ensures that international trade in wild animals and plant specimens does not threaten their survival [23]. Due to the international nature of the trade-in wild animals and plants, its regulation requires international cooperation to protect certain species from over-exploitation [24].

Today, it protects more than 37,000 plant and animal species in different ways, depending on whether they are traded as dried herbs, live specimens, or fur coats [25]. CITES protects over 38,700 species, including approximately 5,950 animals and 32,800 plant species, from over-exploitation through international trade [26]. They are listed in the three CITES Appendices [27]. The species are organised in the appendices based on their vulnerability to global trade.

The turtle checklist in Malaysia was presented previously, but the current conservation status has already been recorded a long time ago. Therefore, we provide the species checklist of turtles in Malaysia; document the recent status of turtles in Malaysia; and compile the turtle research trends nowadays. We also review the causes of current precipitous declines in turtle and tortoise populations through the examination of the threatened status of turtles in Malaysia and speculate on the potential causes of extinction in the coming century. In doing so, we list threats and describe additional research required for long-term sustainability.

## 2. Turtle's type in Malaysia

The 'hard-shelled' Cheloniidae advanced around 60 million years prior, and the 'delicate-shelled' Dermochelyidae developed approximately 90 million years prior [28,29]. The Cheloniidae contain six surviving species in five genera: the Flatback turtle (*Natator depressus*), the Green turtle (*Chelonia mydas*), the Hawksbill turtle (*Eretmochelys imbricata*), the Loggerhead turtle (*Caretta caretta*), the Kemp's ridley turtle (*Lepidochelys kempii*) and the Olive ridley turtle (*Lepidochelys olivacea*). The Leatherback turtle (*Dermochelys coriacea*) is the only animal species in the Dermochelyidae family that is still alive [30].

There are seven sea turtle species (Dermochelyidae and Cheloniidae) worldwide, with five nesting in Southeast Asia. Some of these species are shown in Table 1, and Figure 1 shows that 17% of the turtles that were studied can be found locally. The other two species are the Kemp's ridley turtle, which only lives in the western Atlantic Ocean, and the Flatback turtle, which only lives in Australia (though its feeding grounds extend into eastern Indonesia) [31].

Testudinidae (Land Tortoises): There are 60 land tortoise species recognised worldwide, with Malaysia accounting for 8% of the 24 species (Figure 1). The majority of them live in semi-arid, dry open habitats like grasslands and deserts [32]. Only five Southeast Asian species have adapted to different environments, including humid, forested habitats and cooler temperatures in a lower montane forest [31,33]. Table 1 contains some examples.

Asian Hard-shell Terrapins (Geoemydidae) have the most turtle family species, with approximately 40 species of 14 genera found in Southeast Asia and 70 species found worldwide. Malaysia has the most turtle species (46 per cent) (Figure 1). DNA sequencing has recently revealed hidden diversity in this group; for example, the Cyclemys leaf terrapins are now classified as six distinct species [31]. Table 1 shows some examples.

The Big-headed Turtle (*Platysternon megacephalum*) is mainly the only individual from this family, Platysternidae; it is remembered for the superfamily Testudinoidea, which likewise incorporates the Testudinidae (land turtles), Geoemydidae (Asian hard-shelled terrapins), and Emydidae (new world reptiles). This numerous turtle has a head so large that it cannot be retracted into its shell [34].

Softshell turtles (Trionychidae) have 30 species worldwide [35], with 15 species in Southeast Asia and six in Malaysia (Table S1). It requires hard, unbending scales or scutes—all else being equal, they have a flexible, rugged carapace [36]. Southeast Asia is home to approximately half of the world's softshell turtles [31,33].

The Snake-necked turtles of the Chelodina family are an ancient group of expert fish-eaters whose long necks must be turned sideways to reach beneath the carapace [37]. There are 16 species in the world [31,39].

The Pig-nosed turtle (*Carettochelys insculpta*) is the only species in the Carettochelyidae family [39]. It is found in just three nations—specifically Indonesia, Papua, New Guinea, and Australia [40]. These species are kept as pets in Malaysia. Their flippers resemble sea turtles, and their carapace is rough, but their most unusual feature is their pig-like nose [31,41].

Turtles from the Emydidae family, which originated in the Americas, are widely available in the world's most popular pet stores [42]. For instance, consider the red ear slider [31].

The turtle family Emydidae (order Testudines, suborder Cryptodira) is a distinct taxonomic unit of approximately 52 extant species classified into 12 genera: Actinemys, Chrysemys, Clemmys, Deirochelys, Emydoidea, Emys, Glyptemys, Graptemys, Malaclemys, Pseudemys, Terrapene, and Trachemys [43]. Except for Trachemys, which is found in South America and the West Indies, and Emys, which inhabits southern Europe, northern Africa, and western Asia, all of these

species are restricted to North America [44]. The relationships between the 12 genera of Emydidae and the species that make up the family are still a bit of a mystery [45].

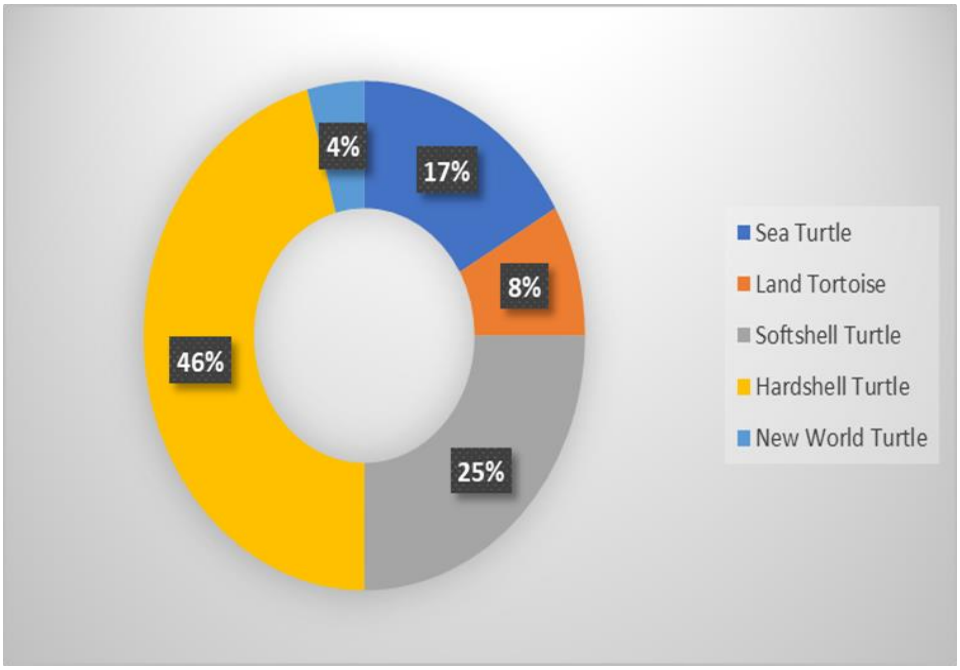



**Figure 1.** The diversity of turtles in Malaysia.

**Supplementary Table 1.** The list of turtles type in Malaysia.

| New World Turtle | Land Tortoise | Sea Turtle | Soft Shell Turtle | Hard Shell Turtle |
|---|---|---|---|---|
| *Trachemys scripta* | *Manouria emys* | *Chelonia mydas* | *Amyda cartilaginea* | *Batagur affinis* |
| | *Manouria impressa* | *Dermochelys coriacea* | *Chitra chitra* | *Batagur borneoensis* |
| | | *Eretmochelys imbricata* | *Chitra indica* | *Cuora amboinensis* |
| | | *Lepidochelys olivacea* | *Dogania subplana* | *Cyclemys dentata* |
| | | | *Pelochelys cantorii* | *Heosemys annandalii* |
| | | | *Pelodiscus sinensis* | *Heosemys spinosa* |
| | | | | *Indotestudo elongata* |
| | | | | *Malayemys macrocephala* |
| | | | | *Notochelys platynota* |
| | | | | *Orlitia borneensis* |
| | | | | *Siebenrockiella crassicollis* |

## 3. Molecular Research Trends

In turtles, molecular markers have been used to describe the mating system in the existing species, with multiple paternity and sperm storage being distinguishing features [46-49]. In contrast, the IUCN lists the Hawksbill turtle (*Eretmochelys imbricata*) as critically endangered [50,51]. *Eretmochelys imbricata* was shown to be mostly monogamous in two studies [52,53] so that sperm could be stored [53].Nonetheless, one of these examinations was conducted in an isolated area of Malaysia [52]. Also, the other one was found in a remote part of the Republic of Seychelles [53]. It has been suggested that different sea turtles may have different

levels of paternity depending on where they live and how many of them there are [47,48,54].

Table 2 contains brief descriptions of genetic markers and how they were used in turtle studies. Prior studies, however, have also used multilocus minisatellites ('DNA fingerprinting') [55]. Furthermore, arbitrary intensified polymorphic DNA (RAPDs) [56], allozymes [57-60], and the enigmatic single-copy nuclear DNA (scnDNA) [61-65], the most commonly used markers for paternity analysis are microsatellites. Other studies have used microsatellites to analyse population genetics [46,64,66-72] and molecular evolution [73,74]. A few report the development of new markers [75,76] or the use of developed attributes for species identification [77]. Microsatellite markers were compared to mtDNA haplotype markers, which are passed down from the mother and have been used for a long time to study the genetic structure of turtle populations and their phylogeography [48, 67, 68].

Due to molecular markers in various fields of knowledge, there has been a significant advancement in molecular genetics techniques in recent years. These markers are practical and risk-free tools that can facilitate an accurate diagnosis. Comparative studies of the genetic variation described by molecular markers and regional morphometric patterns have centred on several wild turtle species [79]. The following molecular markers (Table 1) stand out among those used to detect genetic variability in DNA sequences, such as restriction fragment length polymorphism (RFLP), random amplified polymorphic DNA (RAPD), single nucleotide polymorphism (SNP), mitochondrial DNA (mtDNA) and microsatellites or short tandem repeats (STR) [80]. They stand out because they provide ecological and morphological data that can be used to make different plans for protecting genetic resources [48].

For set preservation systems, molecular markers help to better understand the hereditary variety of faunal species and segment relations. The low genetic variety and star-shaped haplotype network of sea turtles in the EP suggest that the species most likely originated in the Indo-Pacific on a generally late transformative timescale [81, 82]. Most sea turtles have a global distribution, which implies that natural corruption and environmental loss will most likely affect some of their dispersion [83,84]. Assume that these effects reduce availability and population sizes. In that case, genetic diversity will be lost, which will increase the risk of extinction [85] due to a lack of the ability to change and sadness caused by inbreeding [86].

The rate at which hereditary variety is lost in specific animal varieties is a component of the successful population size. This boundary is impacted by an organic entity's characteristic history and segment history [86]. An assessment of crucial boundaries that shape compelling population size is expected to measure the danger of hereditary disintegration and inbreeding gloom [87]. The principal is information on both quality streams via an animal type's geographic appropriation and the mating framework. The mating framework is important because the size of the successful population is less than the size of the registration size if the regenerative slant is high [88].

This section may be divided into subheadings. It should provide a concise and precise description of the experimental results, their interpretation, and the experimental conclusions that can be drawn.

222
223
224
225

**Table 1.** Genetic markers for molecular turtle research.

| | |
|---|---|
| Allozymes | Alleles of a catalyst can be identified by various electrophoretic versatility (usually starch or cellulose acetic acid derivation gels). A very much created method yet has just been utilised a couple of times in turtle concentrates since mtDNA haplotypes and microsatellites turned out to be more famous markers for population hereditary qualities and paternity examination [48,57-60,89]. |
| Anonymous scnDNA | For sea turtles, various PCR preliminaries intensifying mysterious single-copy nuclear DNA loci have been created. Variety in intensified items is inspected by RFLP or sequencing and has not been utilised much since microsatellites turned into the more mainstream nuclear DNA marker [48,61-65,90]. |
| Microsatellites | Pair rehashes of a 1–6 bp 'core' grouping. The evaluation of strategy gives single-locus data. Bespoke introductions for PCR intensification are intended for the microsatellite's flanking areas. The hypervariable idea of a microsatellite is several rehashes of the centre changes effectively. Besides, single-locus information implies more impressive scientific strategies are conceivable than multilocus fingerprinting. It has become a mainstream marker for population hereditary qualities in all. It is the technique for decision for paternity examination of turtle grasps [48,78,91,92]. |
| Minisatellites | This is the first DNA fingerprinting technique. Scattered across the nuclear genome are groups of tandemly dreary 'minisatellite' locales sharing a 10–15 bp 'core' arrangement. Variety in the recurrent number is acquired. Also, minisatellites are exceptionally polymorphic (hypervariable) as genetic markers at the individual and population levels. It was just utilised once for sea turtles since microsatellites turned into the more mainstream marker of decision [55,93]. |
| MtDNA Haplotypes | For sea turtles, it is ordinary to utilise arrangement variety in the control district of mitochondrial DNA (mtDNA). These are named 'haplotypes' because the mitochondrial genome exits just as a single copy (haploid). An around 400 bp piece is enhanced with a standard arrangement of groundworks. In current examinations, the variety is composed by sequencing the improved items. More seasoned investigations may utilise Restriction Fragment Length Polymorphism (RFLP) or other fast screening methods. A normalised classification arranges the haplotypes kept up by the Archie Carr Center for Sea Turtle Research [94,95]. |

| | |
|---|---|
| RAPDs | Arbitrary enhanced polymorphic DNA. A PCR-based procedure utilises short (10 bp) oligonucleotide primers of random arrangement in PCR to create different PCR results of contrasting sizes isolated on an agarose gel. The multilocus technique was momentarily famous for molecular ecology because of the modest and straightforward convention. Anyway, it tumbled from favour when reproducibility turned into an issue. I'm just mindful of one turtle study to have utilised it [56,96,97]. |
| RFLP | Limitation piece length polymorphism. Limitation compounds may cut DNA at explicit acknowledgement groupings. To create parts of reproducible sizes from any substrate DNA particle (nuclear or mitochondrial DNA), they will be isolated by the electrophoresis process. The variety of people in sizes of DNA pieces is brought about by changes that make or dispense with limitation compound acknowledgement successions and is utilised as a sign of hereditary variety. Beforehand mainstream for surveying mtDNA haplotype variety in turtles. However, direct sequencing has, to a great extent, supplanted RFLP. Additionally, momentarily utilised in turtle reads for mysterious scnDNA [48,61-65,98,99]. |

## 4. Conservation Status

### *4.1. The status of the IUCN Red List*

The IUCN Red List categories species into nine groups (Table 2), which [100] defined based on population size, rate of decline, geographic distribution area, fragmentation distribution, and population degree. The importance of applying any measures without extensive information, including suspicion and potential future threats, is emphasised, "so long as these can reasonably be supported." [19] The "Threatened" category includes "Critically Endangered," "Endangered," and "Vulnerable" [21] on its Red List.

Table 3 shows that Malaysia has 24 turtle species, four of which are sea turtles and 20 of which are freshwater turtles (two of which are introduced) [14,101]. According to the IUCN Red List, a sea turtle (*Eretmochelys imbricata*) and six freshwater turtle populations (*Manouria emys*, *Batagur affinis*, *Orlitia borneensis*, *Batagur borneoensis*, *Indotestudo elongata*, and *Chitra chitra*) are critically endangered in Malaysia (Figure 2). In contrast, a sea turtle (*Chelonia mydas*) and five freshwater turtles (*Heosemys annandalii*, *Cuora amboinensis*, *Heosemys spinosa*, *Chitra indica*, and *Pelochelys cantorii*) were endangered in Malaysia. Two sea turtles (*Dermochelys coriacea* and *Lepidochelys olivacea*) and six freshwater turtles were vulnarable (*Malayemys macrocephala*, *Notochelys platynotan*, *Siebenrockiella crassicollis*, *Amyda cartilaginea*, *Manouria iimpressa*, and *Pelodiscus sinensis*). However, two sea turtles were reported by [102] in The Asean Post; a source from the World Wildlife Foundation (WWF) Malaysia shows that the Leatherback turtle is Critically Endangered, and the Olive Ridley turtle is Endangered in the Malaysian ocean. One species is Near Threatened (*Cyclemys dentata*), and two species are Less Concerned (*Dogania subplana* and *Trachemys scoundaripta*).

All the turtle species are distributed all over Malaysia. From the total of 17 species found in Terengganu, four species of sea turtles (*Chelonia mydas*, *Dermochelys coriacea*, *Lepidochelys olivacea*, and *Eretmochelys imbricata*) and 13 species of tortoises (*Trachemys scripta*, *Batagur affinis*, *Batagur borneonsis*, *Coura amboinensis*,

*Siebenrockiella crassicollis*, *Manouria emys*, *Amyda cartilaginea*, *Dogania subplana*, and *Pelochelys cantorii*) [14]. In addition, according to Figure 3, IUCN Red List analysis shows that 29 per cent of Malaysia's turtle species are Critically Endangered and 25 per cent are Endangered.

**Table 2.** The IUCN Red List classifies species into nine groups [19,100,103].

| Classification | Describtion |
|---|---|
| Not evaluated (NE) | Not yet assessed by the IUCN, they indicate species that have not been reviewed enough to assign to a category. |
| Data deficiency (DD) | Offering insufficient information for a proper assessment of conservation status to be made. |
| Least concern (LC) | Unlikely to become extinct soon. |
| Near threatened (NT) | Close to being at increased risk of extinction soon. |
| Vulnerable (VU) | Considered at increased risk of unnatural (human-caused) extinction without further human intervention. |
| Endangered (EN) | A very high risk of extinction in the wild. |
| Critically endangered (CR) | Points in a particular and extremely critical state. |
| Extinct in the wild (EW) | Point survives only in captivity, cultivation, and outside the native range, as presumed after exhaustive surveys. |
| Extinct (EX) | Beyond a reasonable doubt that the species is no longer extant. |

**Table 3.** Checklist of Turtles Species in Malaysia [21,104].

| Common Name | Scientific Name | GenBank Accession | IUCN Red list Status | CITES Appendix | Reference |
|---|---|---|---|---|---|
| Asian Narrow Headed Softshell Turtle | *Chitra chitra* | HQ329770 | CR | I | [105] |
| Hawksbill Turtle | *Eretmochelys imbricata* | GQ152887 | CR | I | [71] |
| Southern River Terrapin | *Batagur affinis* | MN069310 | CR | I | [106] |
| Asian Giant Tortoise | *Manouria emys* | KP268838 | CR | II | [107] |
| Elongated Tortoise | *Indotestudo elongata* | KP268857 | CR | II | [108] |
| Malaysian Giant Turtle | *Orlitia borneensis* | HQ329693 | CR | II | [105] |
| Painted Terrapin | *Batagur borneoensis* | HQ329672 | CR | II | [105] |
| Green Turtle | *Chelonia mydas* | MN124278 | EN | I | [109] |
| Asian Giant Softshell Turtle | *Pelochelys cantorii* | HQ329785 | EN | II | [105] |
| Indian Narrow-headed Softshell Turtle | *Chitra indica* | HQ329771 | EN | II | [105] |
| Malaysian Box Turtle | *Cuora amboinensis* | JN860217 | EN | II | [108] |
| Spiny Turtle | *Heosemys spinosa* | HQ329684 | EN | II | [105] |
| Yellow-headed Temple Turtle | *Heosemys annandalii* | HQ329681 | EN | II | [105] |
| Leatherback Turtle | *Dermochelys coriacea* | KU883273 | VU | I | [110] |
| Olive Ridley Turtle | *Lepidochelys olivacea* | KF894766 | VU | I | [111] |
| Asiatic Softshell Turtle | *Amyda cartilaginea* | HQ329768 | VU | II | [105] |
| Black Marsh Turtle | *Siebenrockiella crassicollis* | HQ329704 | VU | II | [105] |
| Impressed Tortoise | *Manouria impressa* | GQ867670 | VU | II | [112] |
| Malayan Flat-shelled Turtle | *Notochelys platynota* | HQ329692 | VU | II | [105] |
| Malayan Snail-eating Turtle | *Malayemys macrocephala* | HQ329686 | VU | II | [105] |
| Chinese Softshell Turtle | *Pelodiscus sinensis* | JQ844545 | VU | None | [113] |
| Asian Leaf Turtle | *Cyclemys dentata* | HQ329676 | NT | II | [105] |
| Malayan Softshell Turtle | *Dogania subplana* | NC_002780 | LC | II | [114] |
| Yellow-bellied Slider Turtle | *Trachemys scripta* | JF700194 | LC | None | [115] |

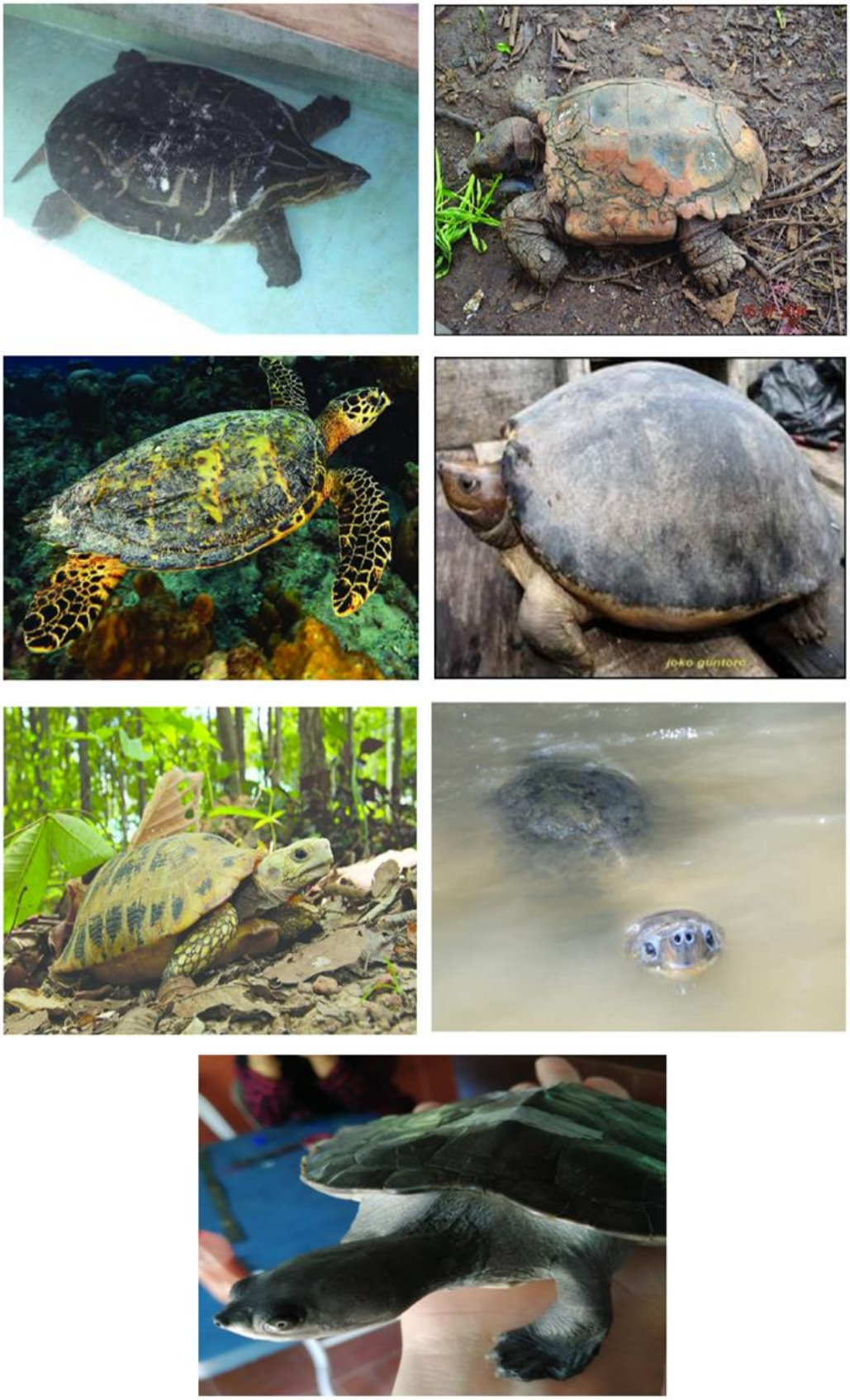


**Figure 2.** The critically endangered turtles in Malaysia. Top left to right: *Chitra chitra* [116]; *Manouria emys* [117]; *Eretmochelys imbricata* [118]; *Batagur borneensis* [119; *Indotestudo elongata* [120]; *Orlitia borneensis* [121]; *Batagur affinis* [122].

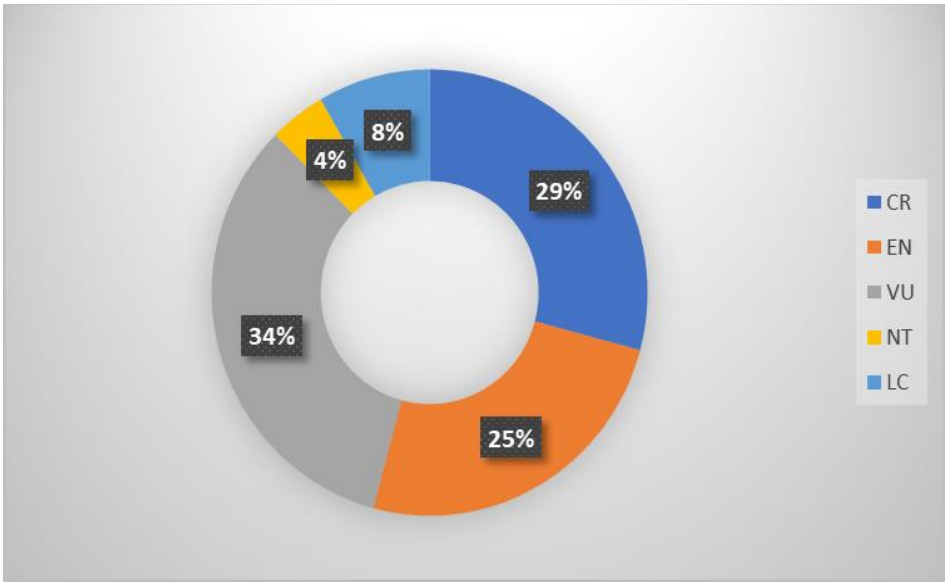



**Figure 3.** Chart of IUCN Red List Status on Turtle.

*4.2. The CITES Appendices*

The Convention's Appendices I, II, and III are lists of species that have different levels or types of protection from over-exploitation [123]. Appendix I contains a list of the most endangered plants and animals on the CITES list. They are almost extinct, but CITES allows international trade in specimens of these species as long as the import is not for commercial use (i.e., a scientific research study) [124].

In Appendix II, there is a list of species that aren't threatened with extinction right now, but if the trade isn't controlled, there is a high chance that they will be in the future. It also includes supposed "similar species," such as species whose standards in exchange resemble species recorded for conservation purposes. Trade-in specimens of Appendix-II species may be authorised by issuing an export permit or re-export permit certificate. No import permit is necessary for these species under CITES (although a permit is needed in some countries with stricter measures than CITES requires). [125].

Appendix III contains a list of species added at the request of a party that already regulates international trade in the species. Specimens of the species in this appendix can only be traded around the world if the right permits or certificates are shown [123].

Analysis of Figure 4 reveals that CITES has classified Malaysian turtles as 67 percent threatened. The species names are *Manouria emys*, *Orlitia borneensis*, *Batagur borneoensis*, *Indotestudo elongate*, *Heosemys annandalii*, *Cuora amboinensis*, *Heosemys spinosa*, *Chitra indica*, *Pelochelys cantorii*, *Malayemys macrocephala*, *Notochelys platynotan*, *Siebenrockiella crassicollis*, *Amyda cartilaginea*, *Manouria impressa*, *Cyclemys dentata*, and *Dogania subplana*. About 25% (*Batagur affinis*, *Chitra chitra*, *Eretmochelys imbricata*, *Chelonia mydas*, *Dermochelys coriacea*, and *Lepidochelys olivacea*) are the most endangered species.

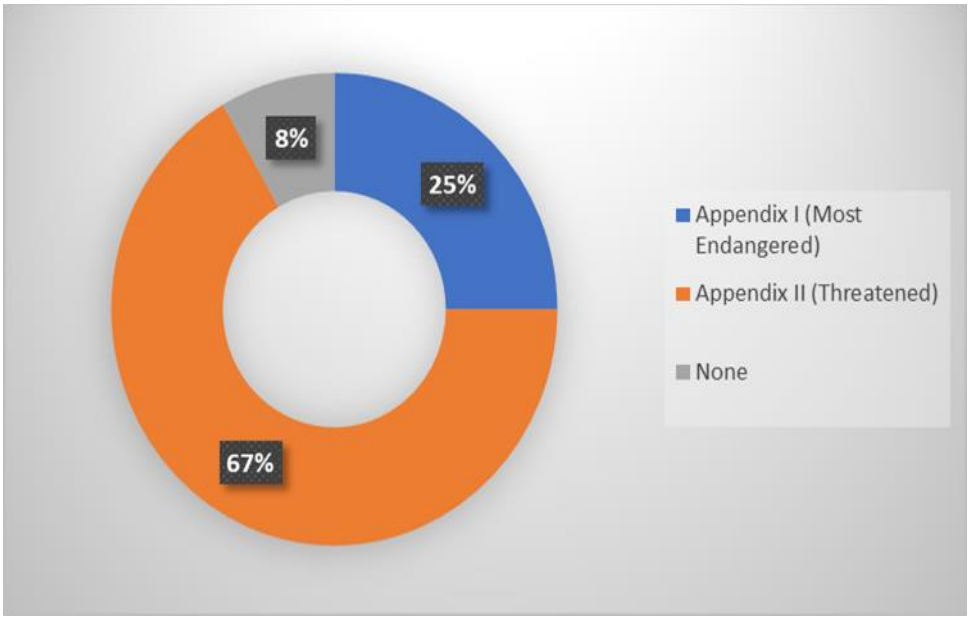



**Figure 4.** Chart of CITES Appendices on Turtle.

## 5. Endangerment factor

**Endangerment factors**

These factors were compiled from IUCN data, the DOF Report, DWNP Report, TRAFFIC Southeast Asia Report, species recovery plans, federal agency responses, and miscellaneous publications on species life history. A complete list of documents used to assign biological attributes to endangered species is available from the authors.

| | | |
|---|---|---|
| Destruction of habitat | Exploitation of eggs | Poaching |
| Fishing fatalities | Tourism disruption | Sedimentation |
| Predation | Coastal reclamation | Sand mining |
| Floating dangers | Forest Clearing | Genetic pollution |
| Industrial development | Diseases | Flooding |
| Climate change | Forest modification | Environmental contaminants |
| Consumption | Agriculture activities | Domestic and international trade |

The [21] population trends for all VU, EN, and CR turtle populations are decreasing. In conclusion, many factors contribute to endangerment. This article documents mostly the work done in Malaysia and the people in charge of making decisions so that it can be used in the future.

The primary causes of endangerment are egg consumption and trade [4,126]. The main threat to turtles is illegal and unregulated turtle poaching by vessels from Hainan (China) and Vietnam [3]. Turtles are hunted for food, medicine, and ornaments [127]. In Malaysia, religious beliefs have reduced the killing of adult turtles for food [128]. On the other hand, building dams, taking turtle eggs, removing riparian vegetation, sand mining, and drowning in fishing nets are some of the turtle's biggest problems [129-133].

According to [134,135], the most critically endangered tortoise and turtle species may become the most sought after due to their scarcity, which makes them especially valuable in the pet trade, hunting, and habitat degradation. [136] reports that they are eaten, collected, butchered, and traded in large numbers; they are used for pets, food, and traditional medicine—eggs, juveniles, adults, and body parts are all exploited indiscriminately, with no regard for sustainability [137]. Their habitats are being destroyed, developed, fragmented, and polluted at an alarming rate [138,139]. Species all over the world are threatened or vulnerable, with many critically endangered. Others are on the verge of extinction, and a few have already perished [140]. Humans are threatening the extinction of countless aeons and turtles [141].

Genetic pollution, aside from overt and highly impactful conservation threats such as overexploitation and habitat destruction, the global turtle fauna is also increasingly facing another insidious threat: genetic pollution caused by human-facilitated hybridisation and introgression from introduced and invasive species [142-146]. Although it is not entirely new, the current scale is unprecedented. Some taxa have already been impacted in the past. This is most likely true for Pelodiscus Asian softshell turtles. These turtles have been farmed and traded for hundreds of years. As a result, different species and local genetic lineages have been moved, leading to different taxa and lineages in both farms and the wild [147,148].

Similarly, the historical introduction of *Mauremys reevesii* to Japan resulted in massive hybridisation with the native [149]. Another historical case of human-mediated admixture of genetic lineages is known from European pond turtles (*Emys orbicularis*). The non-native populations on the Balearic Islands, which were most likely introduced during Roman times [150], are of admixed origin [151]. Another population with genetic signatures of an old or ancient introduction of *Emys orbicularis hellenica* was discovered near Rome [151,152] within the range of another subspecies (*Emys orbicularis galloitalica*). But unlike in the past, when only a few turtle species were affected, genetic pollution has become a big problem in protecting nature in recent years. This is because of the huge pet and food trade and because people are moving around more.

Today, genetic pollution is also caused by the well-meaning addition of genetically mismatched turtles to endangered local turtle populations (usually, but not always, by turtle fans acting in uncoordinated ways), the release of genetically different pet turtles that are too numerous or have been abandoned, and the large-scale release of turtle shipments that have been seized, especially in Southeast Asia. Some endangered *Emys orbicularis* populations at the northern edge of its range [153,154]: genetic evidence for restocking with several different subspecies) and in southern France [152,155]: restocking with non-native *Emys orbicularis hellenica* instead of native *Emys orbicularis*. Examples of genetic pollution caused by abandoned pet turtles include *Chrysemys picta bellii* from British Columbia, introgressed by non-native subspecies [49] and Antillean (Trachemys) introgressed by red-eared sliders (*Trachemys scripta elegans*) [156]. As previously stated, some of the cases involving European pond turtles are related to genetic contamination caused by abandoned pet turtles. In Taiwan, hybridisation between *Mauremys reevesii* and *Mauremys sinensis* has been observed in the wild in released trade animals [157]. [158] say that keeping genetic lineages, subspecies, and species that are well-defined and mostly pure and not hybridised is important and should be a top priority. Therefore, in Malaysia, the two introduced species potentially cause genetic pollution.

## 5. Future Research and Recommendations

Several commendable research lines would also aid in our understanding of the growing issues and threats driving turtles to extinction. Table 5 discusses and summarises these points.

**Table 5.** Summary of recommended future research priorities.

| Topic | Method |
|---|---|
| Ecosystem effects | Monitor key turtle habitats to generate baseline data. Mesocosm experiments. Team up with other research disciplines and industries. Create strategies to identify and measure the trophic exchange of plastic, related poisons and bioaccumulation Explore the effect of plastics on the cycle of benthopelagic coupling [159]. |
| Impacts on nesting beaches | Record perceptions of experiences with sea shore garbage for females and hatchlings. Use oceanographic demonstrating to conjecture how and when key waterfront regions are prone to be affected by plastic contamination [159]. |
| New sites | The examination is to recognize new nesting zones, especially if current nesting locales become unsatisfactory because of improvement or environment driven change [161,162]. |
| Embryology | Creating and assessing a solid gauge of hatchling wellness, understanding endocrine impacts on embryology, and further examinations on the home site choice job in hatchling creation [161]. |
| Molecular | Hope to fuse numerous ways to deal with understanding the spatial biology of turtles, counting hereditary qualities [163], natural biomarkers like stable isotopes [164]. |
| Conservation Management | Designing management strategies with SMART (specific, measurable, achievable, achievable, realistic and time based) objectives that permit assessment, variation and the advancement of proof based preservation will be critical to deciding the board achievement of current and future ventures [162]. |
| Climate Change | Understanding cumulative impacts or developing conservation responses to climate change [165]. |
| Threats | Thought of future dangers and their management in decision processes like horizontal planning, [166].GIS ought to give novel experiences about patterns and can enormously help with understanding the effects of dangers and the adequacy of relief [167,168]. |
| Habitat Restoration | The carrying capacity of territory is a significant thought in living space reclamation [169]. A few creators have looked to explain generally or current-carrying capacities of specific biological systems [170,171], albeit significantly more work is required here. |
| eDNA | Streamlining field techniques for turtle eDNA assortment, further testing primer explicitness through trial of tests containing numerous species' DNA, and creating primers focusing on other turtle networks could extraordinarily improve recognition paces of uncommon species [172]. |
| nDNA | Nnuclear DNA markers (e.g., microsatellites, SNPs) are expected to confirm and further, assess the hereditary portrayal of turtles in the EP as the information from mtDNA markers just reflect variety among female genealogies [47,70]. |
| Microbiology | Harmful microorganisms such as viruses, bacteria, parasites, and fungus that has not yet been investigated on turtles trough metabarcoding, which has the potential to spread among or between hosts. Aside from that, future research could look into the impact of the dominant phylum (Proteobacteria) and genus (Cetobacterium) [122]. |

To distinguish explicit from common-sense preservation activities, it is necessary to examine the information and protection status of each species [173]. Protection status is frequently based on IUCN-proposed measures, which take into account factors such as the number of people remaining, the size of the current geographic conveyance, and data on idle dangers [19]. The restricted assets are given for turtle preservation in many countries, including Malaysia. [174] says that sometimes you need a target method to help you focus on species.

We believe that our work will help to collect more reliable data on turtles and address the threats to Malaysia's most vulnerable species. Our research can help determine which species require management plans and investment from

government agencies. Furthermore, the identified research priorities can assist researchers and students in identifying the least studied topics that are more critical for producing conservation recommendations [175]. [176] says that it is important to focus human and financial resources on the most important problems. They also say that governments and regulatory authorities should work together to make sure that laws and rules are enforced more effectively [177,178].

It is critical to encourage short-to-medium-term studies in ecology and molecular systematics, as well as medium-to-long-term demographic studies that are biologically representative and can be used to guide conservation and management efforts. Malaysian continental turtle species face significant research challenges. They entail leaving our geographical and thematic comfort zones to face the difficulty of gaining access to lesser-known species. Developing studies necessitate significant effort over long periods of time. May should bring together a wide range of expertise from fields such as taxonomists, ecologists, and molecular biologists. Those research outputs may directly raise public awareness of turtles' plight.

## 5. Conclusions

In a small number of species, we face a turtle endurance crisis that is both severe and extinct. Without intervention, valuable species will become extinct over the next few decades. Some of the future research requirements listed in this review may assist researchers in collaborating now to save these animals for which we are so passionate. This review's benefits may help readers understand the risks and threats to turtles. Setting goals for how long we should be able to last and how safe we should be, as well as making new standards for useful conservation techniques.

## 6. Patents

**Supplementary Materials:** The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Table S1: The list of turtles type in Malaysia.

**Author Contributions:** Conceptualization, Y.E. and S.A.M.S.; methodology, M.H.M.S; validation, S.M.S and Y.E; formal analysis, M.H.M.S.; investigation, M.H.M.S and S.M.S.; resources, Y.E. and S.A.M.S.; data curation, S.M.S and Y.E.; writing—original draft preparation, M.H.M.S.; writing—review and editing, Y.E and S.M.S.; visualization, Y.E and S.A.M.S; supervision, Y.E; project administration, Y.E. and S.A.M.S.; funding acquisition, Y.E. and S.A.M.S. All authors have read and agreed to the published version of the manuscript.

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